of the hour bids us look forward with cheerful optimism.

R. S. Woodward.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
*THE PRESENT STATE OF GEODESY.**

The problems of geodesy, like those of most sciences, enter upon new phases with the accumulation of facts bearing upon them. The problem of determining the amount of the earth's compression was added to that of determining the size of the supposed sphere as soon as Newton had demonstrated its oblateness. The controversy to which Newton's theory gave rise was settled by the famous geodetic operations of the eighteenth century which furnished the cardinal facts in regard to the earth's figure and size.

What may be regarded as the slow progress of a more precise knowledge of the earth's dimensions since that time must be attributed to the difficulties inherent in the problem.

In the first place the dimensional measurements must necessarily be confined to the continental areas which occupy but three elevenths of the earth's surface. The configuration and relationship of these areas make it impossible to girdle any section of the earth by direct measurement.

Secondly, the admeasurement of these areas is far beyond the reach of individual enterprise and can only take place when the practical needs of governments suggest the utility of great mensurational surveys which at the same time and without great additional expense will furnish the data required for a more perfect knowledge of the spheroid. In making this statement it is not forgotten that individuals and governments did undertake in all ages measurements for the purely scientific purpose of determining the size of the earth, for the desire for knowledge on this subject may be reckoned coeval with intellectual development of man.

Happily it may be said also that by their collective action the governments of the world have shown in recent times that it is considered a governmental function to support and promote researches in this branch of science. I allude, of course, to the existence of the International Geodetic Association. It will not be out of place to say in this connection that the association exists by virtue of a formal convention between the participating governments, which are, at the present time, the United States, Japan and Mexico and all the European nations save Portugal, Roumania and the group south of the Danube. No account of geodesy would be complete that failed to consider the aims and labors of this association. Its history is part of the history of geodesy since 1861. At that time it began its career as the Mittel Europäische Gradmesung. In a few years it expanded into an European association and in 1886 it became international.

It is not generally known that it was this association which instigated the French government to invite the world to establish an international bureau of weights and measures at Paris. Without detracting in any way from the labors of Bessel, Clarke and others in intercomparing geodetic standards, the successful labors of the bureau which in consequence was established in Paris removed at least some of the difficulties that were encountered by the investigators in this branch of science, and by those engaged in the practical work of the measurement of the earth.

The history of geodesy is full of instances of confusion and wasted energy due to the lack of a common standard, and the results of many arc measures which would

* Address of the vice-president and chairman of Section A—Mathematics and Astronomy, American Association, Philadelphia, December, 1904.

at least have great historic interest are utterly lost to us, because we can not make even a respectable guess at the units used. The adoption of an international unit of length and its necessary auxiliary, a common thermometric scale, and the provision which the various governments made for the reference of their measuring apparatus to a common unit was a step of fundamental importance.

The association as such has no control over the geodetic operations conducted by the different governments. Its function is to be the intermediary where cooperative action is needed, and to discover and point out along what lines the greatest need for information exists.

In pursuance of these duties it has helped to perfect the European systems of triangulation by showing where missing links should be supplied, not only by measurement of angles and bases but also by additional astronomical observations. It has made absolute gravity determinations with all the accuracy demanded by modern science and has caused suitable connection to be made by relative measures between widely scattered pendulum base stations, and it has instituted unique relative gravity measures, to which further reference will be made. It organized and maintains the stations for observing the variation of latitude in regard to which it should be remarked that it is the desire of the association to continue the observations beyond the year 1906, which marks the end of the ten-year period for which that service was tentatively organized. The association strongly desires not only to continue but to extend the service to the southern hemisphere and other latitudes than those now occupied by the permanent stations, and to obtain the cooperation of suitably situated observatories in their endeavor to discover the cause of the phenomena.

That the problem of determining the earth's dimensions could not be solved by simply measuring two arcs in suitable localities was brought home to geometers by the anomalous results obtained in the eighteenth century. For instance, according to Lindenau the combination of the two American arcs, Mason and Dixon's, measured in 1764, and that of Peru, measured a quarter of a century earlier, gave a value of one five-hundredths for the earth's compression. The value derived from those measured in Great Britain alone was about nine times as great, or one fifty-fifth, while those made in France, considered by themselves, gave one one-hundred-and-fiftieth. It is not now important to inquire whether these differences are not in part due to the crudities of the methods of measurement employed. They were sufficiently real to throw doubt on the belief that the earth could be represented by a regular mathematical figure. Finally, the existence of local deflections of the vertical as affecting the amplitude of arcs was recognized, but not taken into account save, perhaps, by arbitrary exclusion of stations showing exceptionally large deflections.

The method of finding an osculating spheroid from arc measures remained in its essence that of taking averages of measurements reduced to the geoidal surface. The differences between the observed directions of the vertical and those computed on an assumed spheroid of reference were treated as if they were accidental errors of observation. At the present time it is the aim of geodesists to assign to the deflections their proper place in the computations and to interpret them by discovering through them and through gravity measurements the manner of the distribution of masses in the interior of the earth. Thus geodesy is trenching on the domain of geophysics and geology.

In India, in Europe and in the United States the study of these deflections is re-

ceiving special attention. In the last-named countries the junction and correlation of the triangulation, which was formerly disjointed, makes it possible to take up the study. Similarly in this country the completion of the transcontinental arc and its connection with the lake survey triangulation furnished the opportunity and occasion for adopting a standard datum of geographical coordinates for the whole country. This in turn furnished the deflections of the vertical referred to a common origin of coordinates on the same spheroid and made it possible to begin the study of the form of the geoid in this country over a very extended area.

The investigation has so far been extended over the eastern part of the United States. Here as elsewhere it was found that the curves of elevation of the geoid above the spheroid reflect perceptibly the visible topographic features.

A preliminary statement of the scope of these investigations was recently given before the International Geographic Congress by Mr. Hayford, the chief of the computing division of the Coast and Geodetic Survey. From it I quote as follows:

> The conclusion that for the eastern half of the United States and the adjacent portion of the Atlantic the theory of isostasy is true to a considerable extent is reasonably safe. The conclusion that the depth within which the isostatic compensation takes place is 205 miles is one which may be modified considerably as the investigation proceeds.
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> The investigation thus far leaves the signs of the corrections to the constants of the Clarke spheroid of 1866 uncertain.

Mr. Hayford will give before this meeting an account of the method devised by him of computing the topographic correction. The task of computing this correction to a distance of 4,000 kilometers for each of say 500 stations has been rendered possible by this method, which is, therefore, referred to by me as a distinct advance in geodesy.

It is hoped that the completion of the study of the data now available in regard to the deflections will serve as a guide to the most effective use in the future of the pendulum, and it is on this account largely that pendulum observations have been for the present deferred by the coast survey. They are, however, being actively made by other nations.

A new impetus was given to relative gravity observations by the adoption of short and light pendulums in place of the heavy seconds' pendulum. Aside from their portability, their lightness insures greater invariability for the knife edges, simplifies the task of securing uniformity of temperature and pressure in the metal cases in which they are swung, and the ease with which a low and constant pressure can be maintained in the case insures the continuance of the swing through so long a period that the errors of the chronometer or other timepiece are eliminated. Thanks to the efforts of the International Geodetic Association, the widely scattered base stations have been connected with the central station of the association at Potsdam, where a long series of absolute gravity determinations were brought to a successful conclusion two years ago. The association has available now the data from nearly 1,800 stations scattered over various parts of the globe. A most interesting and valuable extension of relative gravity measures to the surface of the ocean was made two years ago. The principle upon which the new method depends is that if the atmospheric pressure is determined at the same time and place by means of a mercurial barometer on the one hand and by the temperature of the boiling point of water on the other, the observed height of the barometer will be affected by gravity at the place, while the result by the hypsometer will be independent of it. According to Dr. Hecker, who carried out the laboratory

experiments as well as the actual test at sea, the suggestion that the two instruments might be used for the determination of differences of gravity was first published in 1894 by Dr. Guillaume, of the International Bureau of Weights and Measures at Paris. Dr. Mohn, of Christiania, successfully applied the method by actual tests in various places in Norway for the purpose of determining the gravity reduction of the barometer for meteorological purposes. Doctor Hecker installed his apparatus on a steamship and sailed from Hamburg to Rio Janeiro via Lisbon, Portugal, and Bahia, Brazil, and returned on another steamer to Lisbon, making observations both ways. The results of his observations have been published and show:

1. That the intensity of gravity on the Atlantic Ocean between Lisbon and Bahia is nearly normal, and agrees with the theoretical values computed by means of the general formula published by Helmert in 1901.

2. That the difference of gravity at sea in shallow water and in deep water corresponds approximately to the difference of gravity between coast stations and inland stations.

These results were submitted to the Geodetic Association at the last meeting. Means were provided for another expedition and last March Dr. Hecker began his journey, crossing the Indian Ocean and the Pacific by way of Melbourne and Sydney to San Francisco. Thence he recrossed to Japan and China, and we may look forward to an early statement of the results, which are being awaited with deep interest.

As in the case of the pendulum already referred to, there has been in the last decade a decided improvement and simplification in instrumental means and methods of work. It is only necessary to cite the introduction of tapes and wires for primary base measurement, the introduction of the transit micrometer for the elimination of personal equation in time determinations, and of the leveling instrument, devised in the coast survey, which is making its way into more general use. With the use of the latter there has just been satisfactorily completed the first precise line connecting the Atlantic, Gulf and Pacific mean sea levels in the coasts of the United States.

In all countries the determination of the mean sea level and the establishment of so-called bench marks in the interior are being actively prosecuted as they furnish part of the required geodetic data.

In beginning I referred to the measurement of continental areas. Let us see what has been accomplished as to the extent of areal measurement since Snellius introduced triangulation into geodesy 289 years ago. In our own hemisphere, so far as I am able to learn, about the three-hundredth part of one per cent. of the area of South America has been covered; of Mexico about one per cent.; of the United States about five per cent. Geodetically the British possessions in the western hemisphere are barren. We may say that less than three per cent. of the western hemisphere has been triangulated.

In the eastern hemisphere we find that about forty per cent. of Europe has been covered, but if we leave out Russia the percentage rises to eighty per cent. for the rest of Europe.

The triangulation of Asia is furnished by India and Japan, Java and Sumatra and amounts to about four per cent.

Australia shows about two per cent., Africa about two and six tenths per cent., making a total for the eastern hemisphere of about seven per cent.

If we exclude the north and south polar regions a little over six per cent. of the available land area has been triangulated, or about one and one half per cent. of the total surface of the globe. These figures

are accurate enough for the purpose for which they were compiled, that is, to show the relatively small area covered. There is, however, another side to the picture, the hopeful one. In South America the arc of Peru is being remeasured and extended by the French government. As the work is being carried out with the advice of the most distinguished mathematicians of France, the results will be, in their importance, out of all proportion to the extent and area involved.

Mexico has made a brave beginning and is working towards a connection with an extension of the ninety-eighth meridian measurement, of which the United States has completed about three quarters of the amplitude lying in her own domains. Work on the Pacific coast arc has been resumed and it has nearly been completed from San Diego to the Columbia River.

Two years ago the Russians and Swedes jointly completed an arc in Spitzbergen between latitudes 76° and 81°. The European arcs are being extended eastward by Russia, and one must look forward to the ultimate connection between the Russian triangulation at Astrakhan or Orsk and the Indian triangulation, however improbable it may seem if looked at from a political view point.

In Africa the work of extending the South African arcs northward from the Cape towards Alexandria is well under way, and no doubt need be entertained that the British and Germans will carry it through.

A general review of this part of the field of geodesy shows that while some great geodetic measurements have been completed or are approaching completion, new ones are being undertaken under the fostering care of different governments.

Reasoning from the experience of the past, we may conclude that the solution of one problem in geodesy will disclose the existence of another, and from the trend of the investigations of the present that other than purely mathematical and astronomical sciences will be advanced by the search for their solution.

That the progress of the branches of science to which this section of our association devotes itself was greatly affected by the problems of geodesy was pointed out by Humboldt in language which may fittingly conclude these remarks:

> Except the investigations concerning the parallax of the fixed stars, which led to the discovery of aberration and nutation, the history of science presents no problem in which the object obtained—the knowledge of the mean compression of the earth and the certainty that its figure is not a regular one—is so far surpassed in importance by the incidental gain which, in the course of long and arduous pursuit, has accrued in the general cultivation and advancement of mathematical and astronomical knowledge.

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*FUTURE DEVELOPMENTS IN PHYSICAL CHEMISTRY.**

It has been the custom of the retiring officers to discuss the development of some portion of that field of chemistry in which they were most interested. Since the president of the American Chemical Society will speak on physical chemistry tomorrow night, it has seemed to me that I might break with tradition and discuss the future of physical chemistry rather than its present or its past.

We have reached a critical stage in the development of the electrolytic dissociation theory. The work of Kahlenberg has shown that there are a number of facts which we did not anticipate and which we can not explain satisfactorily at the present time. The recent experiments of Noyes show that the dilution law does not hold for any strong electrolyte and that the

* Address of the vice-president and chairman of Section C—Chemistry, Philadelphia, 1904.